

Training our energy systems

By: Kelly Mackenzie, MSC, BPE, AFLCA trainer

Regardless of what mode of exercise we are using, we can train all three of our energy systems. There are physiological adaptations that can occur within the muscle cells when using training techniques specific to each of the energy systems. Understanding the sources of energy for each of the systems, how energy can be restored as well as how the three systems interact are essential in putting together sound training programs. Further, an appreciation of what training does to the muscle cell's ability to use energy, both acutely as well as chronically, will strengthen a trainer's ability to ensure ideal training for results.

Energy!

Adenosine triphosphate (ATP) is the stored form of energy within the body. ATP is an adenine nucleotide bound to three phosphates. ATP will convert to ADP (adenosine diphosphate) and a free circulating phosphate (Figure 1). This conversion breaks the bond of the third phosphate, releasing the stored energy. This energy is what is used for all life functions of a cell. Similarly, energy can be restored for future use by reattaching a phosphate to the ADP.

As an overview, there are three energy systems: the Anaerobic Alactic system (AnA), the Anaerobic Lactic system (AnL) and the Aerobic system (AER). Each creates ATP, which can then be converted into energy for muscle activity. The sources of ATP as well as where within the cell the ATP is created is what differentiates each of the systems.

The Anaerobic Alactic System

There is a limited amount of stored energy (ATP) within the muscle cells. This is the energy of the AnA system, also known as the ATP-CP system. Typically, there is sufficient ATP stored within the muscle to last several seconds. As ATP is converted to release energy, creatine phosphate (CP) which is also present in the muscle cells, will split so as to reform new ATP (Figure 2). So long as CP is present, new ATP continues to fuel the muscle cells with energy. However, there is also a limit of CP stored in the muscle, and typically this system will be tapped out within 10 - 15 seconds of intense activity.

Because the ATP is in a "ready to go" form, it provides instant energy to the working muscles. As the name suggests, this system requires no oxygen (anaerobic) and also has no by-products such as lactic acid (alactic). Time is needed in order to regenerate ATP and CP stores within muscle cells, however the recovery may be little to no activity. Although stored ATP and CP are used up quickly, they will recycle themselves within a very short time. There is some indication that training this system may increase ATP stores within the muscle as well as increase creatine phosphate stores, thus enhancing the ability to create more immediate energy.

The Anaerobic Lactic System

Muscle glycogen is also stored in limited amounts within the muscle. When energy beyond what can be provided from the AnA system is needed, glycogen, a carbohydrate, breaks down into glucose and can then produce ATP within the muscle cell. Due to the multiple steps to create energy, the AnL is a slower process than the

AnA system. This system will continue to provide energy for working muscles so long as there is muscle glycogen present. These stores will typically provide energy for bouts of intense exercise lasting ~ 60 up to ~ 90 seconds.

The conversion of muscle glycogen to ATP happens outside of the mitochondria in the muscle cells, therefore the presence of oxygen is not needed (anaerobic). Without oxygen, however, lactic acid is formed. Lactic acid can produce discomfort in the working muscles as well as limit performance. Ideally, recovery should be a low intensity activity. This allows for better circulation, thus removing the lactic acid and normalizing the pH level of the cells as well as delivering the byproducts (lactate) to the heart and then the liver, where it can be recycled to new potential energy.

As with the AnA system, muscle glycogen stores can be replenished within the working cells with appropriate rest. Training the AnL system can prove beneficial in improving the buffering capacity of the cell (to combat lactic acid). Further, training can lead to an increase in muscle glycogen stores as well as an improved efficiency to convert glycogen to glucose.

The Aerobic System

The AER system is unique from the others in that it can convert any of the three macronutrients into energy. With this energy system, ATP is created within the mitochondria (power house) of the working muscle cells therefore presence of oxygen is required. The breakdown process is much slower than either the AnA or the AnL, however there is a seemingly endless supply of energy for the cells. Thus, the AER system provides continuous supply of energy, however it cannot tolerate higher intensities as the energy is not produced fast enough for such activity.

Similar to the AnA, there are no metabolic wastes produced during the AER conversion of energy, therefore recovery from efforts does not have to be active. Training the aerobic energy system has many known benefits. Ones related to energy stores include an increased ability of the muscle cells to utilize more oxygen due to increased size and numbers of mitochondria as well as an increase in heart stroke volume, resulting in more delivery of substrates to the working muscles.

Interaction of the three systems

Using a 5 km running race, it is possible to better comprehend how the energy systems interact. As an activity is begun, the AnA system kicks in as it has energy “ready to go” when the start gun sounds. As these immediate stores quickly deplete, the AnL takes over. In that it is somewhat slower in producing energy, it cannot provide for the same intensity. Therefore the runner cannot keep the “start” speed and will slow down a bit. The AnL is limited by muscle glycogen stores, therefore it is the AER system that will take over for longer durations in that it can use limitless sources of fuel for energy. The runner would be able to hold a pace for which the aerobic system could provide energy – a pace slower than either of the anaerobic systems. This illustrates the continuum between the three systems.

However, it is important to realize that it is not as simple as switching gears. Rather, there is always a predominant system which is contributing more energy than the others. In other words, the runner would be using some energy from all three systems for most of the 5 km, even though the aerobic system would be the dominant contributor. Further, what happens when the runner gets to a steep hill? If she is working aerobically, that system may not provide for the extra energy needed to get up the hill. In this case, the two anaerobic systems, that have restored themselves during the race, will kick in and get the racer up the hill. Similarly, a sprint finish would require

extra energy above what the aerobic system could provide. Training all three systems allows for the best adaptations specific to each system.

Training the Systems

Training methodologies are governed by several factors: % effort, length of effort, and work to rest ratio. Understanding these factors can permit the leader to develop sound programs that meet the goals while also provide variety for the participants.

As discussed the AnA system is an all-out effort lasting up to 10 seconds. Depending upon your fitness environment, there are many ways of incorporating this training into your regime. In the weight room, a trainer could prescribe one to several repetitions of heavy explosive lifts which utilize multi-jointed actions (such as squats, hack squats, power cleans, bench press). In a studio, water, or outdoors, leaders can provide opportunity to do plyometrics type activities (such as several squat jumps, bounds, explosive jumps or pushes) or very short sprints, so long as the efforts are close to 100% & not exceeding the 10 second timeline. Interval training (multiple sets) is an ideal way to train this system. Typically, a work to rest ratio between 1:3 and 1:5 is recommended for regeneration of the ATP stores. Full rest is ideal for this type of training. This would mean your participant would go all out with the activity for up to 10 seconds & would follow with a little to no activity break between 30 & 50 seconds. Then, the activity would be repeated. These efforts are very intense. Ensuring a good warm up prior to beginning any intervals are key.

The AnL system is also easily trained in many environments. Efforts should be gauged to be “all out” while lasting 30 – 90 seconds. In the weight room, sets of 8 – 12 reps at a harder effort (hypertrophy sets) depend greatly on the AnL energy stores. In other fitness arenas, hard effort activities that create that lactic acid burn within 30 to 90 seconds are using AnL predominantly (such as isometric holds, circuit stations, longer power intervals, slightly longer sprints). Typically, a ratio of 1:2 or 1:3 is recommended ensuring active recovery. Because of the lactic acid, it is not advised to have participants stop immediately following the effort. Rather, choose an easier activity to do for ~1 to 3 minutes, before asking the participants to go begin the next interval. For instance, in a cycling class, having the participants climb a steep hill as hard as they can for 30 seconds followed by a fast downhill light resistance spin for 1 minute before the next climb would be very appropriate. It is important to let participants know that the toll on the working muscles as well as the accumulation of metabolic waste may cause second day soreness. Similar to resistance training, it is recommended to take 48 – 72 hours break between training sessions for the same muscle groups.

The aerobic system can be trained using continuous training methods such as steady state heart rates between 55 – 85 % HRmax. Any activity that can keep the heart rate in that zone is effectively training the system. That said, it is pertinent to realize that there must always be some progression in activity so that the body does not get accustomed to only one work rate. In other words, if a person were to do the same running trail, for the same amount of time, at the same effort & heart rate, a fitness plateau would be achieved over time. In order to better challenge the AER system, the route would need to change, or the run would need to be lengthened, or the pace / heart rate increased. Conversely, interval training can also effectively aid the AER system. In setting up intervals, leaders should look for challenging activities that near the higher end of the aerobic heart rate zone & aim to hold the activity for longer than 3 minutes. With aerobic intervals, a typical work:rest should be 1: ½ or 1:1. As there are no metabolic wastes produced, full rest can be prescribed or a light to moderate activity. In deep water, traveling hard across the pool for > 3 minutes followed by a moderate

stationary activity before traveling again would fit the bill. IN a bootcamp class, having participants line up & take turns through an obstacle course, with rest between bouts might also be very appropriate for the AER system.

In summary, there is great opportunity to train 1, 2 or all 3 energy systems in any class. Intervals provide great variety & enjoyment. They create an environment for participants to challenge themselves & work at their personal best. Caloric expenditure during intervals is often higher than steady state activity and there is evidence that EPOC (excess postexercise oxygen consumption – aka extra calories burnt to return to homeostasis) is higher with intervals than aerobic training. Bringing intervals into a fitness program allows participants to be more ready for many daily activities while also preparing them for more efficient energy usage.

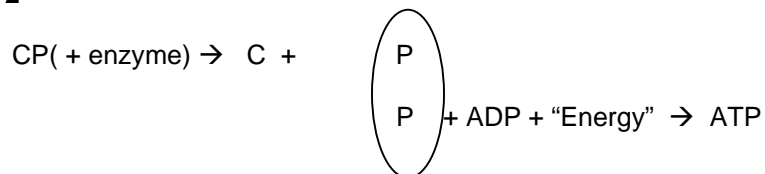
Table 1 – Ideal interval training guidelines

System	Length of repetition	Intensity	Work : Rest	Type of recovery
Anaerobic Alactic	1 – 10 seconds	Very very high	1:3 to 1:5	Full rest
Anaerobic Lactic	30 – 90 seconds	High to very high	1:2 to 1:3	Low to moderate activity
Aerobic	3 min or longer	Moderate to high	1: ½ to 1:1	Full rest or moderate activity

Figure 1



Figure 2



The following exam is based upon Kelly Mackenzie's article "Training our Energy Systems". These ongoing exams are offered to AFLCA certified leaders in each edition of the "Fitness Informer" or can be downloaded from the web site at www.provincialfitnessunit.ca, as an opportunity to gain Continuing Education

Credits. Submission deadline: March 31, 2005.

Please be aware that answers may involve application of the information from the article and not simply recall. **Worth: One Theory Credit.**

CEC Multiple Choice Exam – Circle your answer. Mail this exam and your log book (which will be returned) to the AFLCA. Good luck and be sure to include your name and return address.

Name: _____

Address: _____

1. The predominant energy system used for a shot putter would be:
 - a. The Anaerobic Alactic System
 - b. The Anaerobic Lactic System
 - c. The Aerobic System
 - d. Both anaerobic systems would be used equally
 - e. All three systems would be used equally
2. Analyze a hockey player. Which would be the predominant system used during a shift?
 - a. The Anaerobic Alactic System
 - b. The Anaerobic Lactic System
 - c. The Aerobic System
 - d. Both anaerobic systems would be used equally
 - e. All three systems would be used equally
3. Training the anaerobic lactic system may aid in building tolerance to lactic acid in future exercise bouts.
 - a. True
 - b. False
4. Muscle glycogen is converted inside the mitochondria of a muscle cell to produce ATP, however a byproduct of this conversion is lactic acid.
 - a. True
 - b. False
5. In prescribing 5 second wind sprints, the most ideal recovery would be
 - a. 10 seconds active recovery
 - b. 10 seconds full rest
 - c. 20 seconds active recovery
 - d. 20 seconds full rest
 - e. 60 seconds active recovery
 - f. 60 seconds full rest

6. In prescribing 60 seconds of stair running, the most ideal recovery would be
- 30 seconds active recovery
 - 30 seconds full rest
 - 2 minutes active recovery
 - 2 minutes full rest
 - 4 minutes active recovery
 - 4 minutes full rest
7. Which statement below is TRUE regarding lactic acid?
- Lactic acid is produced with all anaerobic activity.
 - Lactic acid is a byproduct of foods with high pH.
 - Lactic acid is cannot be buffered.
 - Lactic acid is formed inside the mitochondria of a muscle cell
 - All of the above are true
 - None of the above are true
8. Which of the following activities would be most ideal for training the anaerobic lactic system?
- 4 reps of 20 seconds tuck jumps : 50 seconds stairs
 - 10 reps of 100 meters swim sprint : 400 meter easy swim
 - 8 reps of 30 seconds deep water explosive jumps : 90 seconds moderate flutter kick
 - 6 reps of 45 seconds very fast running on a step : 90 seconds full rest
 - none of the above are appropriate
9. Theoretically, taking a creatine supplement would affect the _____ system by _____ resulting in _____.
- Anaerobic alactic; decreasing phosphate stores; more potential energy.
 - Anaerobic alactic; increasing phosphate stores; more potential energy.
 - Anaerobic lactic; buffering lactic acid; longer tolerance of the cell pH.
 - Anaerobic lactic; increasing muscle glycogen stores; more potential energy.
 - Aerobic; bringing oxygen into the cell; more efficient mitochondria.
10. Training the aerobic system results in
- increased stroke volume
 - increased delivery of nutrients to the muscle cells
 - increased size & number of mitochondria
 - increased efficiency of delivery, transport & utilization of oxygen to the muscle cells
 - all of the above are true
 - none of the above are true